

Flame Resistant Fibrous Structures Development

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Final Report

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for

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INTRODUCTION

Since 1986, Albany International Research Co. has been engaged by the Johnson Space Center to conduct studies aimed at development and production of fibrous and flexible structures made therefrom which are to find application in the Space Shuttle and Space Station Programs. In the crew bay area, life support systems and crew flight equipment for the Space Shuttle mission were initially designed to function in a 30% oxygen, 70% nitrogen atmosphere at 10 psia pressure. This oxygen concentration imposed certain fire safety and smoke generation requirements which could not be completely met by commonly available fibers. The purpose of the current program was (1) to investigate potentially useful new polymers, both for fire safety and mechanical properties, (2) to produce fibers from these polymers if necessary and (3) to produce sufficient quantities of qualified fibrous structures, composites, or laminates for use in various areas of the Space Shuttle and Space Station Programs. Over the past six years, we have successfully completed over 200 discrete tasks requested by the NASA Technical Manager.

During the past six years, development efforts have been expended in several major areas in support of Space Shuttle missions and Space Station Freedom projects. The summarized results of several of these major efforts are included in this report. Detailed descriptions of the month-to-month progress on the various tasks can be found in the 71 Monthly Progress Reports which have been submitted during the course of the work.

RESULTS

Conformal Laminate Fibrous Structures

In one of the Advanced Space Suit designs, the mobility joint shoulder and wrist elements were envisaged as being fabricated from flexible coated fibrous structures. In the past, efforts had been made to produce such moldable elements from flat fibrous structures which were coated and then formed into the desired configuration. The purpose of the current effort was to design and weave a seamless tubular structure, form it into the desired configuration, and then coat it on the inside to allow for pressure retention of 8 psia which is the internal pressure of the Advanced Space Suit.

The work initially proceeded in two phases: (1) designing and weaving of a tubular structure to obtain the desired configuration and (2) development of a suitable electrostatic coating technique whereby the formed element could be coated internally. Both efforts were successful in that a tubular, moldable polyester fibrous structure was produced and subsequently coated with a urethane resin. Samples of both coated and uncoated shoulder and wrist elements were submitted to JSC and its contractor for evaluation.

Additional samples of an uncoated, tapered, tubular structure were delivered to the David Clark Company for their use in fabricating an improved wrist element for use with the Advanced Space Suit.

U.S. Patent No. 4,771,518 was issued jointly to Johnson Space Center and Albany International Research Co. on 20 September 1988 detailing the weaving techniques employed to produce these unique fibrous structures.

Woven Tubular Structures for a Crew Self-Rescue Device (CSR)

A pneumatically deployed flexible tube system has been designed by JSC engineers to assist an astronaut who has inadvertently become detached from Space Station Freedom (SSF) to return to the SSF

base under his/her own power during Extra-Vehicular Activity (EVA). The requirements for the tubular structure were specified as follows:

1. 20-foot continuous length, 2-inch diameter
2. Lightweight
3. Seamless
4. High strength
5. Low elongation
6. Capable of retaining 100 psia internal pressure
7. Flexibility at -50°F

An experimental trial was first conducted using polyester fiber. This trial successfully demonstrated the feasibility of the approach. In order to meet the above specified requirements, Kevlar-29 yarn was selected for manufacturing the flight qualified tubular structure and met all the requisite properties.

Maintaining the diameter of the tube to the specified tolerance proved to be one of the major difficulties encountered with Kevlar yarns. Once the proper loom settings were established, however, it became possible to produce the required samples. These were then supplied to Arthur D. Little, Inc. where coating experiments using silicone resin were conducted.

At this writing, work is still underway on this task and it is expected that it will continue during a follow-on contract with JSC.

Beta Fabric Laminates for Regenerative Life Support Systems Project

In support of activities with the proposed Lunar Habitat project, we were asked to prepare a variety of fabrics considered for use in hydroponic experiments currently underway in the Crew and Thermal Systems Division of the Johnson Space Center.

The proposed system involved using fabrics as wicks to carry liquid nutrients from baths to an area where seeds are being germinated to begin the process of supplying food to future residents of the Lunar Habitat. A fiber found to be most suitable for this application is glass-based Beta fiber. A laminate of Beta fabric with polyethylene film was produced and supplied to JSC for evaluation.

Results with the preliminary samples appear promising and work will continue during the next contract.

Other end-item related projects which have been pursued under JSC direction include the following:

- a. "Project Pathfinder" subcontract administration.
- b. "Lunar Boot Sole" subcontract administration.
- c. Evaluation of recently developed high temperature, flame-resistant and high-strength fibers (polyimide, Goretex, Spectra, Ultrapek).
- d. Coated fabric development.

Analytical Laboratory Studies

Over the past six years, we have undertaken many tasks aimed at providing laboratory analyses for specific mission-related projects. Some of the major assignments are listed below:

- a. Fibrous and Non-fibrous Debris Microscopical Analyses
- b. Chemical Analyses of Filter Residues
- c. Infrared Analyses of Various Materials Supplied by JSC
- d. Age and Service Life Studies of Space Suit Bearing Seals
- e. Abrasion Studies (Wear Resistance)
 - 1. Effect of Lunar Dust on Candidate Suit Materials
 - 2. Lightweight Polyester and Nylon Fabrics
- f. Urethane Film Aging Studies
- g. "Blocking" (sticking) Testing of EMU and Glove Bladder Materials

Production of Small Lots of Various Materials for JSC and Its Contractors

One of the major areas of support to JSC under this contract was the production of small quantities of various qualified fibrous structures needed by JSC and/or its contractors for the fabrication of flight items of space hardware. Over 250 such items have been produced. The items include the following types of textile structures:

- a. Broad woven fabrics (Kevlar, Goretex, Polyester, Nomex, PBI)
- b. Narrow woven webbings and tapes (Kevlar, Polyimide, Nomex, PBI)
- c. Knit fabrics (PBI)
- d. Braided cords (PBI, Spectra, Polyimide)

